Senior Thesis

Seasonal Variations of Major Ions at Two Locations along the Olentangy River, Columbus, Ohio

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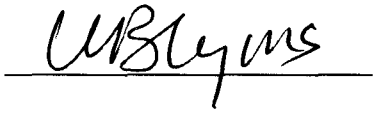

Dr. W. Berry Lyons

Abstract

The Olentangy River is a major tributary of the Scioto River and flows through agricultural lands prior to entering the Columbus metropolitan area. Human activities such as agriculture and urbanization should influence the chemistry of the river water as the river flows through different regions. In addition, there are natural geochemical processes such as chemical weathering that will impart a chemical signature to the water. By observing and analyzing the variation in the stream chemistry through different seasons, we can gain an understanding of how precipitation events, along with natural and human influences, impact the water quality of the river.

River water samples were collected at two locations along the Olentangy River from December 2004 to January 2006. Samples were collected at a location north of Columbus, High Banks metro park (HB), as well as a downstream location, the Boat Launch near Nationwide Arena (BL). The HB location is thought to reflect both natural and agricultural inputs, while the BL location should include urban influences. After collection, the samples were filtered and analyzed for major anions and cations via ion chromatography. Ion concentrations from the samples were compared to stream flow data obtained from the USGS.

The Olentangy River water consists of $Ca > Mg = Na > K$, reflecting the impact of the local geology. In general, all of the major ion concentrations vary with flow, having lower values at high flows. At both sites, calcium and chloride vary by a factor of 3 and 5, respectively through the year. The variation in nitrate is greater, with the lowest values observed in June. Calcium concentrations at base flow conditions varied as much as 43% at BL. The BL site has higher chloride and sodium, generally lower nitrate, and

no trend in calcium and magnesium concentration compared to the HB site. This suggests a source of NaCl from the urban landscape, a nitrate decrease either by dilution or by biological uptake, and little to no addition of source in calcium and magnesium between the two sites.

Acknowledgements

I would like to thank Dr. W. Berry Lyons, Kathleen A. Welch, Dr. Anne E. Carey, and Dr. Carol E. Landis for their guidance and direction. I have become a better person, student, and scientist because of your patience and encouragement. Thank you.

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1. Introduction

1.1 Location

The Olentangy River is a highly urbanized river that is part of the Upper Scioto watershed. It originates in an agricultural area, Crawford County, and flows south through Marion, Delaware, and Franklin counties to the city of Columbus. Just south of Columbus, the Olentangy River joins with the Scioto River. From the confluence it makes it way further south to the Ohio River.

1.2 Geology

The geology of the Olentangy River watershed consists of Paleozoic sedimentary rocks and Pleistocene glacial till. In Delaware County, the geology consists of marine sediments of Paleozoic age. The Olentangy River cuts through the Ohio Shale, Delaware Limestone, and the Olentangy Shale formations (Westgate, 1926). In Franklin County, the geology also consists of shale, sandstone, dolomite, limestone, sand, gravel, clay, and glacial till (Kovach, & Baker, 1966). Figure 1 shows that the main stem of the Olentangy River runs through glacial till in Franklin County.

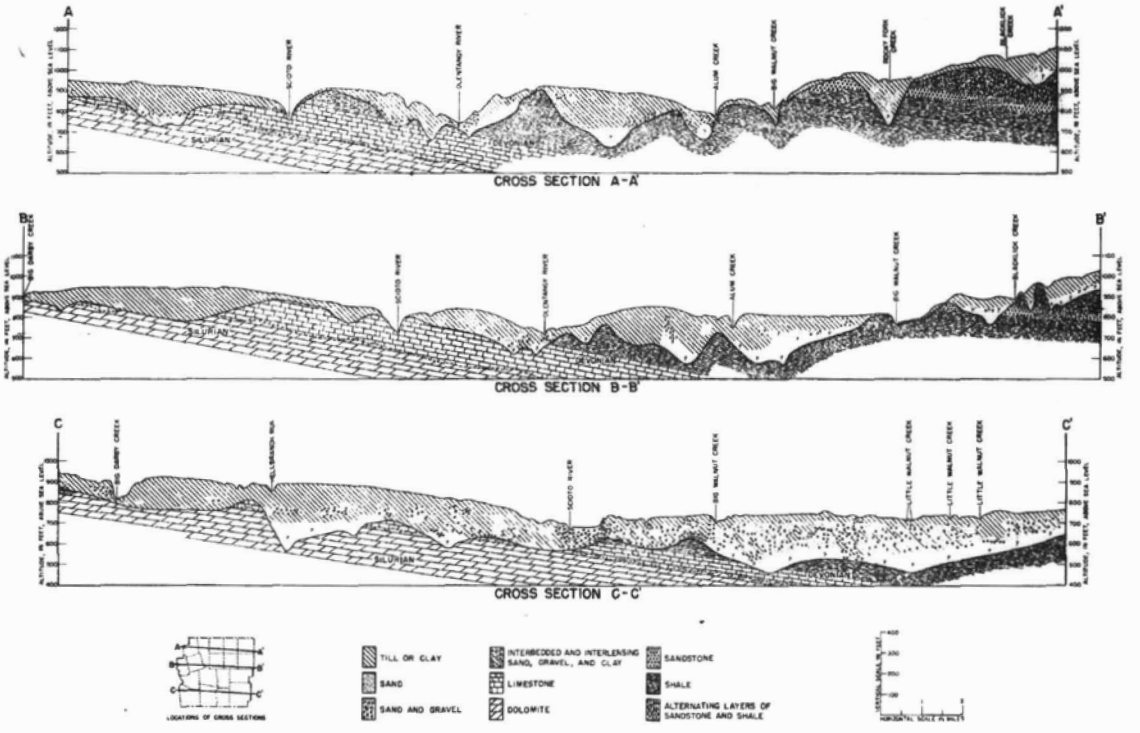


FIGURE 1. Generalized cross sections showing geology of Franklin County, Ohio.

1.3 Stream Hydrology

Stream flow data have been collected by the United States Geological Survey (USGS) from 1955 to present and are available on the USGS website space (11). The Olentangy's mean annual flow over the past 39 years was 13.4 m^3/s. The daily average flow ranged from 0.184 m^3/s on 28 December 1991 to 306 m^3/s on 21 January 1959.

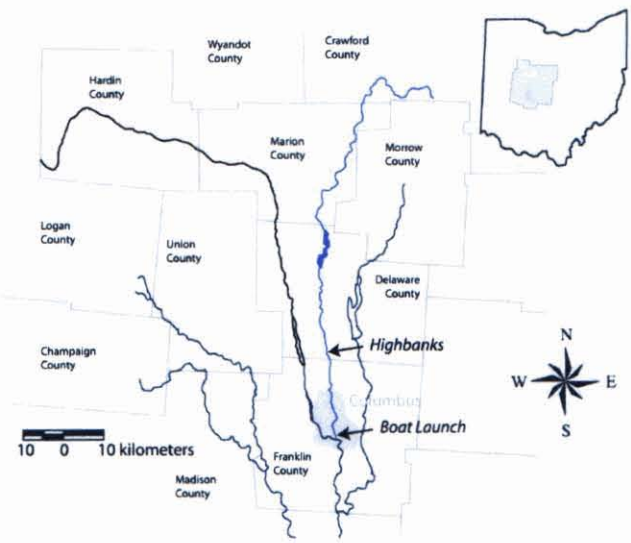
1.4 Objective

The goal of this project was to examine the seasonal variation in the concentrations of major ions in the Olentangy River in the river water at two locations (Figure 2) and examine the influence of the flowrate on major ion concentrations. Although previous research (Carey and Lyons, in press) has demonstrated that up-stream agricultural practices greatly influence river chemistry, my study was to evaluate local,

more urban influences on water quality. It may also be possible to identify other influences on stream chemistry due to local urban landuse and anthropogenic activities.

The most northern sampling site, Highbanks (HB), is located 17.7 km upstream of downtown Columbus within the wooded Highbanks Metropolitan Park, near the intersection of S.R. 315 and S.R. 750 (Powell Rd). The southernmost site, Boat Launch (BL), is located at the Olentangy Boat Launch in downtown Columbus, near Nationwide Arena.

Figure 2. Olentangy River (in blue).



2. Method

2.1 Bottle Cleaning

Samples were collected using one-liter high-density polyethelene (HDPE) Nalgene bottles. Bottles were washed with liquinox detergent, rinsed with tap water 5 times, rinsed twice with deionized 18-MΩ (DI) water, and filled with 10% hydrochloric acid (HCl) over night. They were then rinsed 5 times with DI water.

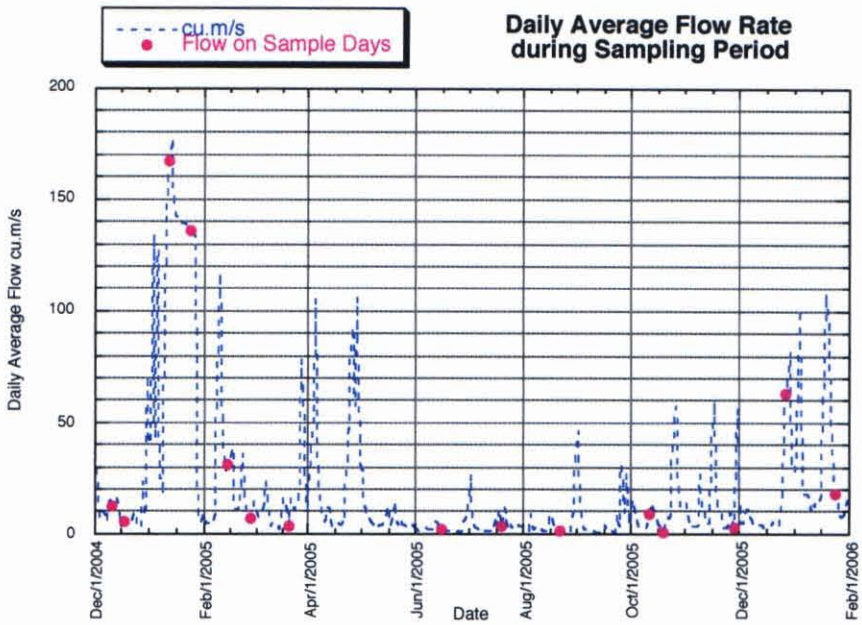
Bottles used to collect filtrate were washed using two different methods. For the filtrate to be used for anion analysis, the bottles were rinsed with DI water and filled with DI to soak overnight. They were then rinsed twice with DI water. For the filtrate to be used for cation analysis, the bottles were filled with 10% HCl to soak overnight and then rinsed 5 times with DI water.

2.2 Collection

Samples were collected approximately one to two times a month from November 2004 through January 2006. The majority of the samples were taken at or below baseflow conditions (Figure 3). Three samples,12 & 24 January 2005 and 27 December 2006, were collected during storm flow conditions (Figure 3). The ~2 meter sampling arm is constructed of PVC pipe and can hold a one-liter sampling bottle. Once the clean sampling bottle is secured, the arm is extended over the water. The bottle is submerged, open-end down, about 1/3 of the way from the surface of the water. The bottle is then turned upstream to release air and to fill it with water. To ensure the least amount of atmospheric contamination, the bottle is rapidly returned to shore and capped while still

submerged. Powder-free Nitrile gloves were worn to avoid contamination from the "capping" hand.

Figure 3. Daily Average Flow Rate during Sampling Period



2.3 Laboratory Techniques

The samples were returned to the water chemistry lab at Scott Hall (Byrd Polar Research Center)and filtered through a polycarbonate membrane Nuclepore™ filters (pore size of 0.4 microns) to remove detritus, sediment, etc. After filtration, the samples were analyzed on a Dionex DX-120 instrument using the techniques outlined in Welch et al. (1996) for major anions (F^-, Cl^-, NO_3^-, & SO_4^-) and cations (Na^+, K^+, Mg^{2+},& Ca^{2+}). This instrument uses a single-piston isocratic pump and an electrical conductivity detector. The eluent flow rate was set to 1.2 ml/min for both anion and cation analysis and the sample loop was 25μl. For the cations, a Dionex IonPac CS12A analytical column (4x250mm) and a CG12A guard column (4x50mm) were used. The eluent was a 0.13% methanesulfonic acid solution. A CSRS Ultra Cation Self-Regenerating

Suppressor was used. For the anions, a Dionex IonPac AS14 analytical column (4x250m) and an AG14 guard column (4x50mm) were used. The eluent is a 1.0mM $NaHCO_3$ and 3.5mM Na_2CO_3 solution. An ASRS Ultra Anion Self-Regenerating Suppressor was used.

Single ion standards each being 1000 mg/L were combined to make a multi-element stock standard for calibration. The multi-ion stock standard reflects the relative proportions of ions found in natural waters. The multi-element stock is diluted further to make 6 or 7 calibration standards, depending on the expected range of concentrations in the samples (Tables 1& 2).

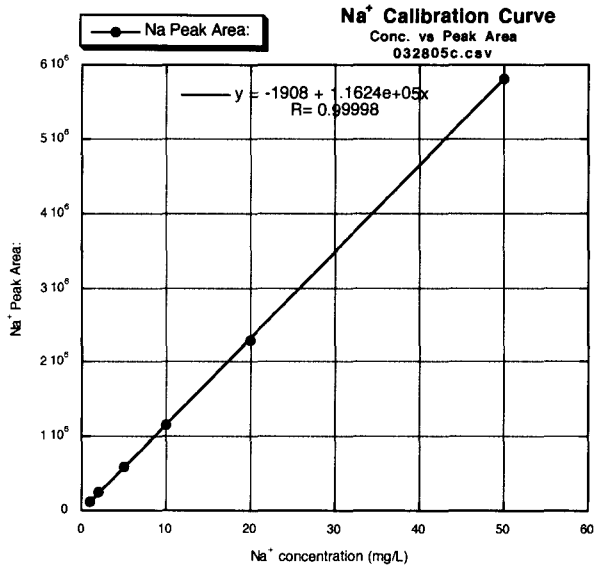
Table 1. Concentrations of ions in the anion standards (mg/L).

	F^-	Cl^-	Br^-	$N\text{-}NO_3^-$	PO_4^-	SO_4^-
stock	10	100	20	10	50	100
std6	5	50	10	5	25	50
std5	2	20	4	2	10	20
std4	1	10	2	1	5	10
std3	0.5	5	1	0.5	2.5	5
std2	0.2	2	0.4	0.2	1	2
std1	0.1	1	0.2	0.1	0.5	1
stda	0.05	0.5	0.1	0.05	0.25	0.5
stdb	0.02	0.2	0.04	0.02	0.1	0.2
stdc	0.01	0.1	0.02	0.01	0.05	0.1
stde	0.005	0.05	0.01	0.005	0.025	0.05

Table 2. Concentrations of ions in the cation standards (mg/L).						
	Li^+	Na^+	NH4	K^+	Mg^{2+}	Ca^{2+}
stock	1	100	10	20	50	50
std6	0.5	50	5	10	25	25
std5	0.2	20	2	4	10	10
std4	0.1	10	1	2	5	5
std3	0.05	5	0.5	1	2.5	2.5
std2	0.02	2	0.2	0.4	1	1
std1	0.01	1	0.1	0.2	0.5	0.5
stda	0.005	0.5	0.05	0.1	0.25	0.25
stdb	0.002	0.2	0.02	0.04	0.1	0.1
stdc	0.001	0.1	0.01	0.02	0.05	0.05
stde	0.0005	0.05	0.01	0.01	0.025	0.025

These standards of known concentration were analyzed and a regression line comparing the peak areas to the concentration was created in order to calibrate the instrument (Figure 4). This calibration was used to calculate the concentration in the samples and to check for error during preparation. Once sample concentrations were calculated, mg/L was converted and reported in molar units.****(sentence out of place? Or unnecessary?)

Figure 4. Example Calibration Curve for Sodium



The SPEX check standard is a NIST (US National Institute of Standards and Technology) certified, multi-element standard that is used as an independent check. The check standard was diluted by a factor of 100 and analyzed as an unknown sample to confirm the accuracy of the calibration standards.

Table 3. Precision and Detection Limits

	Cl^-	$N\text{-}NO_3^-$	SO_4^-	Na^+	K^+	Mg^{2+}	Ca^{2+}
Precision (% rel. std.dev)	2.3	2.5	2.1	0.8	6.1	4.0	2.7
Detection Limit (mM)	0.028	0.007	0.010	0.043	0.005	0.021	0.012

Presion and detection limits are listed in Table 3. Precision was calculated as percent relative standard deviation of several duplicates. The detection limits were determined by the lowest concentrations used for calibration. HCO^{3-} was calculated by subtracting the sum of the anions from total cation in equivalents for each sampling event. This technique is a proven one given the high precision of the major cation and anion data (Lyons et al., 1992).

3. Results

3.1 Ranges of Major Ion Concentrations

The range of the ions measured during the course of this sampling period is shown in Table 4. The highest daily average flow on a sampling event during this period was 118 m^3/s on January 24th, 2005. The lowest daily average flow on a sampling event was 0.9 m^3/s on October 19th, 2005.

Table 4. Range of Ion Concentrations at Each Site.

	Cl^- mM	SO_4^- mM	$N\text{-}No_3^-$ mM	Na^+ mM	K^+ mM	Mg^{2+} mM	Ca^{2+} mM	HCO_3^- µ equiv.
Highbanks	0.291-2.26	0.204-0.895	0.068-0.309	0.259-1.79	0.068-0.149	0.263-1.01	0.701-2.10	1.68-5.00
Boat Launch	0.437-2.56	0.214-0.894	0.018-0.339	0.362-2.08	0.066-0.143	0.289-1.00	0.738-2.24	1.75-5.28

3.2 Concentration of Major Ions over Time

Sample dates were plotted versus ion concentrations for both Highbanks and Boat Launch (Figures 5 & 6) to determine if there were any seasonal variations. Concentrations were relatively low in January 2005 and began to increase in February with a maxima in the spring of 2005. There were some exceptions to this pattern; K^+ decreases continually from November 2004 to August 2005, increases in November, and as in the previous year, decreases into January 2006. Ca^{2+} decreases in July and August and increases in October.

Figure 5. Anion Concentrations over Time

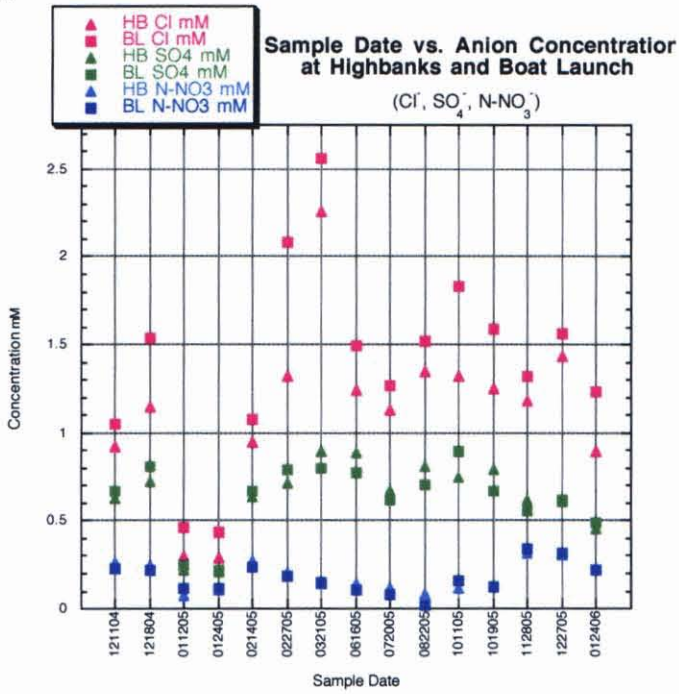
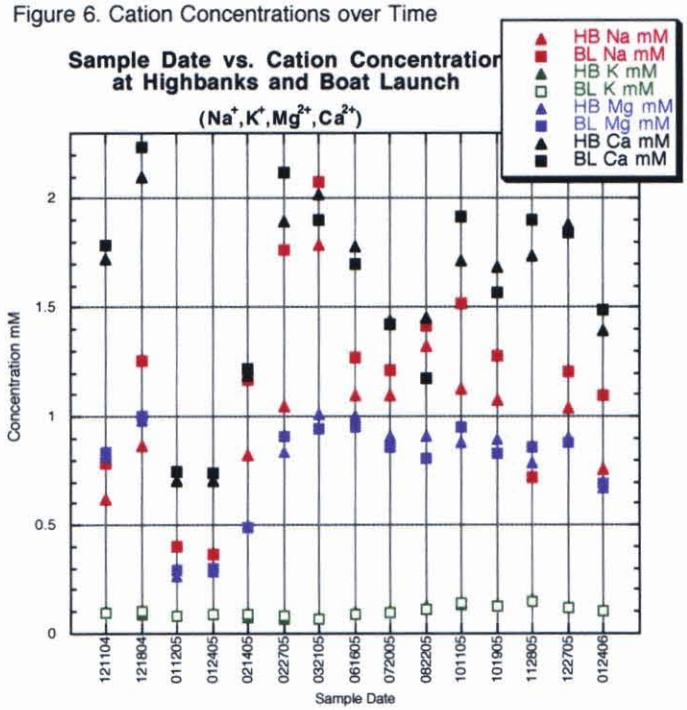


Figure 6. Cation Concentrations over Time



3.3 Concentrations and Daily Average Flow

Overall, the concentrations of anions and cations show an inverse relationship with flow (Figure 7). With an increase in flow, the ion concentration decreases; thus, dilution via rainfall plays an important role in controlling the major ion chemistry of the Olentangy River. However, nitrate showed no correlation as demonstrated by very low r values (Figure 7). K^+ concentrations at both Boat Launch and Highbanks also are not inversely related to the flow. K^+ concentrations are maintained within a range of 0.07mM and 0.15mM regardless of the amount of flow.

Figure 7. Daily Average Flow Rate vs Anion Concentrations

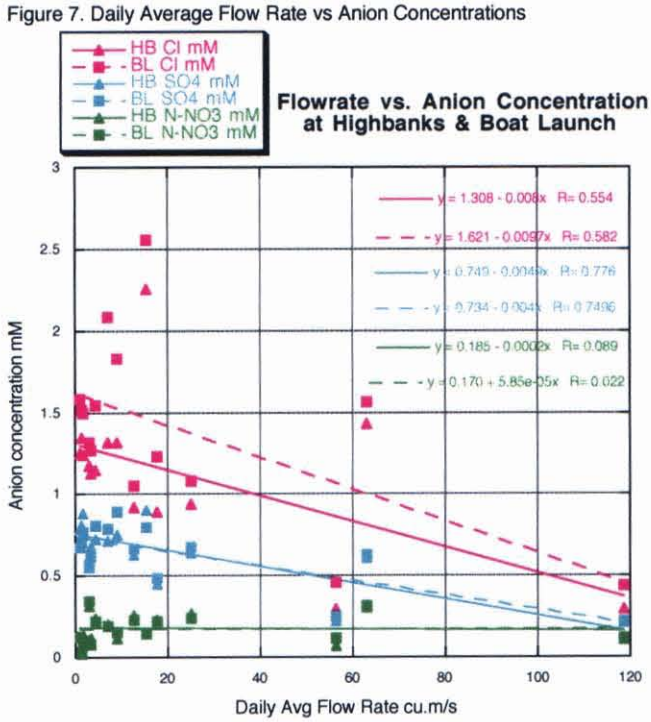
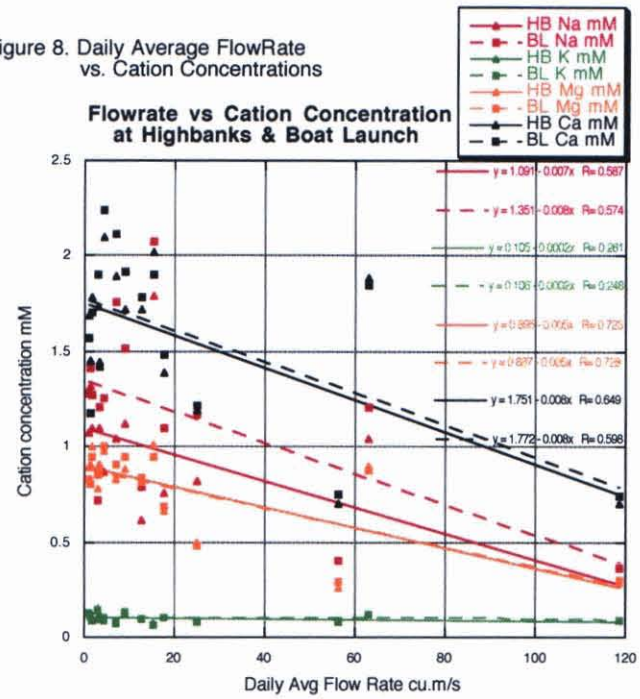


Figure 8. Daily Average FlowRate vs. Cation Concentrations



3.4 Differences between Highbanks & Boat Launch

The concentration ranges of all the ions measured were similar at both sites (Table 5). However, the Highbanks site had lower values of Cl^- and Na^+. By subtracting the upstream (HB) concentrations from the downstream (BL) concentrations, one can assess the input of chemicals as the Olentangy River flows through the northernmost part of metropolitan Columbus. Na^+ and Cl^- concentrations are almost always higher at Boat Launch than Highbanks (Figure 9). During the fall and winter, concentrations of Ca^{2+}, Mg^{2+}, and SO_4^- are higher at Boat Launch. These ions are higher at Highbanks than at Boat Launch during the spring and summer (Figure 10).

Figure 9. Differences in Na^+ & Cl^- Concentrations at each Sampling Event

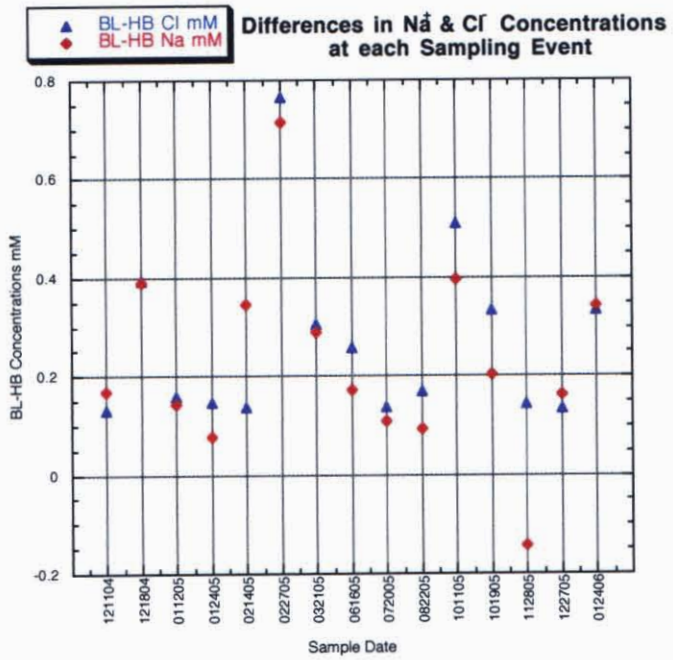
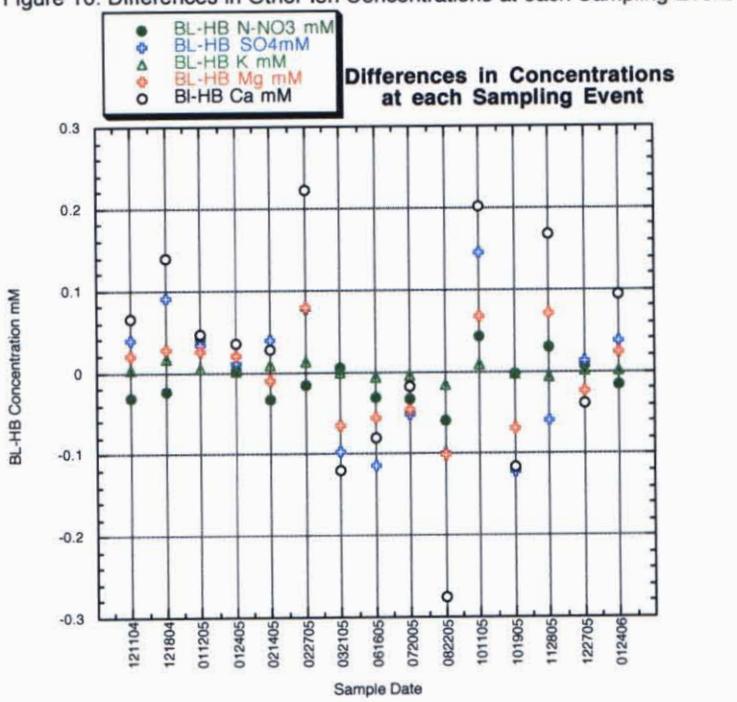


Figure 10. Differences in Other Ion Concentrations at each Sampling Event



4.Discussion

4.1 Ranges & Sources of Major Ion Concentrations: Comparison to Other River Systems

The ranges of concentrations listed in Table 4 can be compared to the average mean global river concentrations determined by Holland (1978) (Table 5). Generally, the range of ionic concentrations in the Olentangy River is greater than the mean global river values. The exceptions are Na^+ and K^+ where the lowest values in the Olentangy approximate the global means.

Table 5. Holland (1978)- Chemistry of the Atmosphere & Oceans

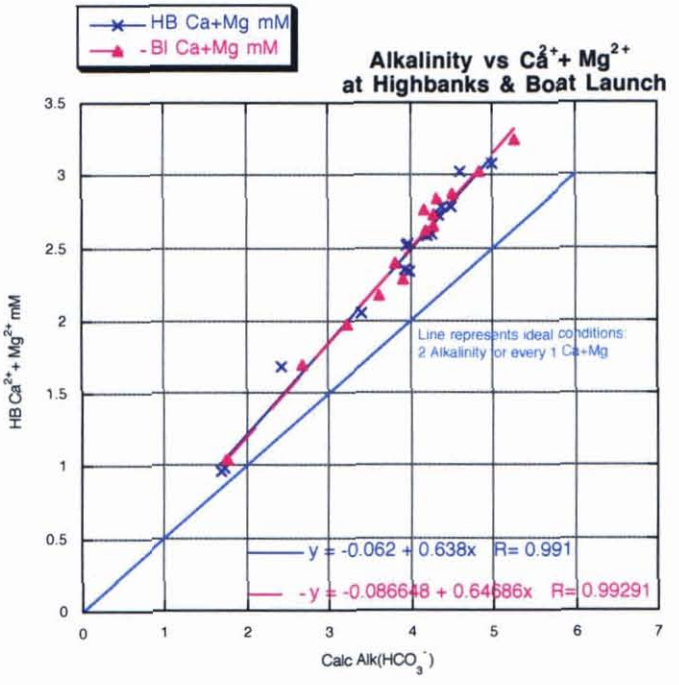
Ion	Average Worldwide River Concentrations mM	Range of Concentrations at Highbanks mM	Range of Concentrations at Boat Launch mM
HCO^{3-}	0.96	1.68-5.00	1.74-5.28
SO_4^{2-}	0.12	0.20-0.90	0.21-0.90
Cl^-	0.22	0.29-2.25	0.44-2.56
Ca^{2+}	0.37	0.70-2.10	0.74-2.24
Mg^{2+}	0.18	0.26-1.01	0.29-0.95
Na^+	0.26	0.26-1.79	0.36-2.08
K^+	0.07	0.068-0.150	0.066-0.143

Table 6. Stallard & Edmond's River Classification	Total Cation Charge (microeq/l)	Approximate TDS (mg/l)	Predominant Rock Type	Characteristic Water Chemistry
	<200	<20	Intensely weathered (cation-poor) siliceous rocks and soils thick regolith	Si-enriched; low pH; $Si/(Na^+ + K^+)=2$: high $Na^+/(Na^+ + Ca^{2+})$
	200-450	20-40	Siliceous (cation-rich); igneous rocks and shales (sedimentary silicates)	Si-enriched; (higher Si from igneous and metamorphic rocks); $Si/(Na^+ + K^+)=2$; intermediate $Na^+/(Na^+ + Ca^{2+})$
	450-3000	40-250	Marine sediments; carbonates, pyrite; minor evaporites	$Na^+/Cl^- = 1$; $(Ca^{2+}+Mg^{2+})/(1/2\ HCO_3^- + SO_4^-)=1$; low $Na^+/(Na^+ + Ca^{2+})$
	>3000	>250	Evaporites; CaSO4 and NaCl	$Na^+/Cl^- = 1$; $(Ca^{2+}+Mg^{2+})/(1/2\ HCO_3^- + SO_4^-)=1$; high $Na^+/(Na^+ + Ca^{2+})$
Olentangy at Highbanks	2338.1 - 6363.83	169.44 - 448.25		
Olentangy at Boat Launch	2526.8 - 6193.8	86.4 - 239.4		

In order to compare this work to Stallard and Edmond's (Berner & Berner, 1996) chemical classification of rivers, Table 6, total cation charge (micro eq/l) and total dissolved solids (TDS)(mg/l) were calculated at high flow and low flow for Highbanks and Boat Launch. As noted in the Table 6, both sampling sites exceed the total cation charge, and the TDS for rivers that flow through sedimentary rocks during low flow. Because the local geology of the Olentangy River watershed is well constrained, the stream chemisty must be influenced by an outside source of salt in order to place it into the "evaporite" category of Stallard and Edmond (Table 6). This suggests that deicing salt from the local highways is impacting the system as a whole. Recently Gardner and Carey (2004) have demonstrated that road deicing salt greatly impacts the urban portion of the Olentangy River throughout the entire year, not just in the winter. The vast

majority of rivers and streams in the Northeastern U.S. are impacted by road deicing activities (Kaushal et al., 2005; Jackson & Jobbágy, 2005).

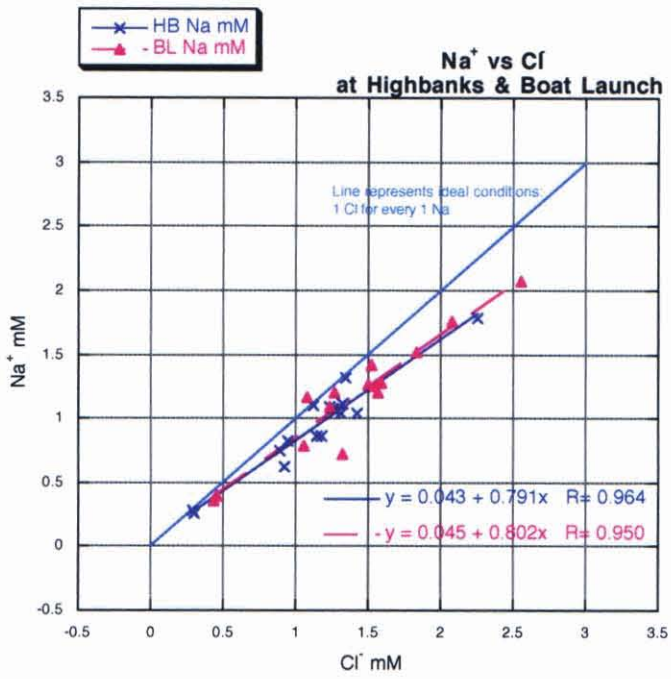
Figure 11. Alkalinity vs Calcium + Magnesium



Since the geology of the watershed is predominately Paleozoic sedimentary rock, especially carbonates, HCO_3^-: Ca^{2+} and HCO_3^-: Mg^{2+} ratio of 2:1 can be expected when limestone/dolomite is being dissolved. Figure 11, shows that there is more Ca^{2+} and Mg^{2+} than HCO_3^-, that can be explained by carbonate weathering alone. The glacial till that the river runs through in Franklin County, contains a myriad of rock types that might be able to explain the differences in the observed chemistry. NaCl deicing salt is typically used on the local highways, but impurities in the deicing salt could include $CaCl_2$ (Richter & Kreitler, 1993) also would help to explain the higher Cl^- relative to Na^+ in the river water (Figure 12). Saline groundwater (Figure 13) may be an additional source of NaCl during baseflow conditions (Westgate, 1926). The Ca^{2+} to Mg^{2+} ratio of the river water is approximately 2:1(Figure 14). This suggests either that $CaCO_3$ is the primary rock type

being weathered or that $CaMg(CO_3)_2$, dolomite, is being weathered along with an additional source of Ca^{2+}.

Figure 12. Na^+ vs Cl^- at Highbanks & Boat Launch



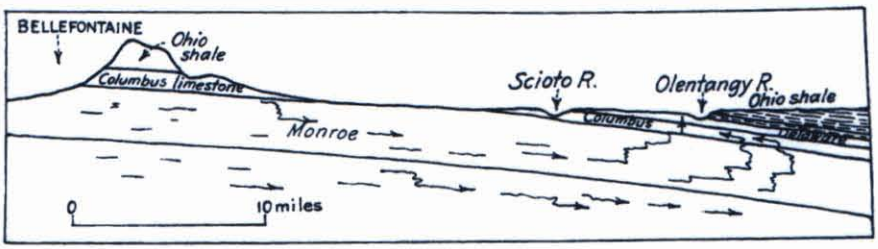
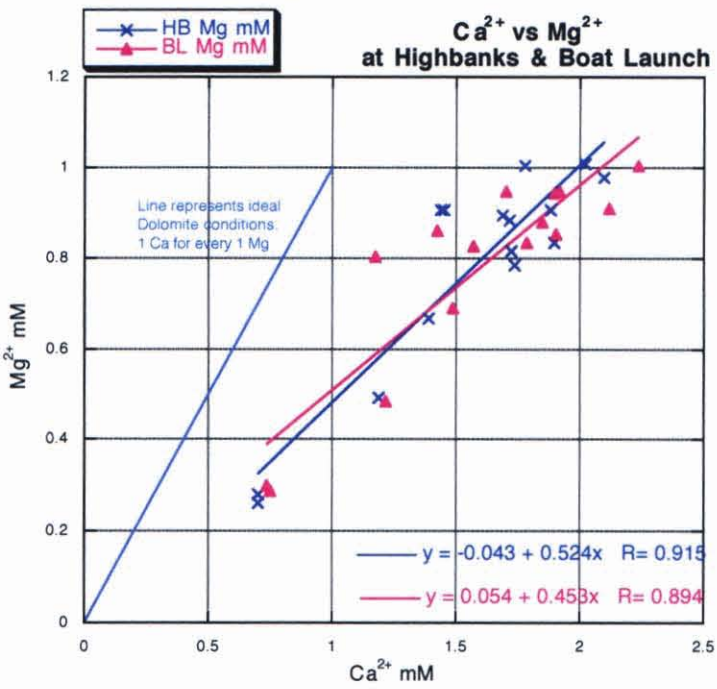


Figure 13. Underground Water Flow, Delaware County

Figure 14. Calcium vs Magnesium



4.2 Differences between Highbanks & Boat Launch:

State Route 315 runs alongside of the Olentangy River in both Delaware and Franklin Counties. The reason for the difference in Na^+ and Cl^- between Highbanks and Boat Launch (Figure 9) is undoubtedly due to increased input of NaCl, via road deicing, in the more urban portion of the watershed. As noted above, Gardner and Carey (2004) recorded the input of Cl^- from urban storm sewers to be as high as 39 mM, and Na^+ and Cl^- are the most highly enriched ions (relative to river water) in highway runoff. Figure 9 shows that there was always an increase in Na^+ and Cl^- concentrations as the stream flows to the Boat Launch site from the Highbanks site. Statistically, however, using a two-tailed t-test, the data used to derive Figures 9 & 10, supports the null hypothesis that there is no

difference between the two sites (P=0.155). Regression statistics are shown in Appendix B.

Other than Na^+ and Cl^-, most of the variations in the other ion concentrations (Figure 7) are very small and suggest little change in concentrations between the two sites.

5. Conclusion

- The Olentangy River water consists of $Ca^{2+} > Mg^{2+} = Na^{+} > K^{+}$, reflecting the impact of the local geology.
- Concentration of the ions is inversely related to flow, except for K^{+} and $N\text{-}NO_3^{-}$ concentrations.
- Using Stallard and Edmond's River Classification scheme, the chemistry of the Olentangy River falls in the evaporite deposit category suggesting an input of NaCl from deicing salt.
- Numerically there is an increase in Na^{+} and Cl- concentrations from Highbanks to Boat Launch.
- Statistically there is no difference in the major ion concentrations from Highbanks to Boat Launch.

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Appendix A

Relationships of Major Ion Concentration with Flow

Relationships of Major Ion Concentration & Flow (For Figures 7 & 8)			
Ion	R value at Highanks	R value at Boat Launch	Significance?
Cl^-	0.554	0.582	yes
SO_4^-	0.776	0.750	yes
$N\text{-}NO_3^-$	0.089	0.022	no
Na^+	0.587	0.574	yes
K^+	0.261	0.248	no
Mg^{2+}	0.723	0.728	yes
Ca^{2+}	0.649	0.598	yes

Appendix B

Statistics

Statistics: t-Test: Two-Sample Assuming Equal Variances

	HB Cl mM	BL Cl mM	HB N-NO3 mM	BL N-NO3 mM	HB SO4 mM	BL SO4 mM
Mean	1.13	1.40	0.179	0.172	0.638	0.634
Variance	0.217	0.299	0.007	0.008	0.043	0.038
Observations	15	15	15	15	15	15
Pooled Variance	0.258		0.007		0.041	
Hypothesized Mean Difference	0		0		0	
df	28		28		28	
t Stat	-1.46		0.253		0.057	
P(T<=t) one-tail	0.078		0.401		0.478	
t Critical one-tail	1.701		1.701		1.701	
P(T<=t) two-tail	0.156		0.802		0.955	
t Critical two-tail	2.048		2.048		2.048	

	HB Na mM	BL Na mM	HB K mM	BL K mM	HB Mg mM	BL Mg mM
Mean	0.937	1.168	0.101	0.102	0.774	0.771
Variance	0.146	0.213	0.001	0.000	0.059	0.053
Observations	15	15	15	15	15	15
Pooled Variance	0.179		0.001		0.056	
Hypothesized Mean Difference	0		0		0	
df	28		28		28	
t Stat	-1.50		-0.158		0.030	
P(T<=t) one-tail	0.073		0.438		0.488	
t Critical one-tail	1.701		1.701		1.701	
P(T<=t) two-tail	0.146		0.876		0.976	
t Critical two-tail	2.048		2.048		2.048	

	HB Ca mM	BL Ca mM	HB Calc Alk (HCO3-)	BL Calc Alk (HCO3-)
Mean	1.56	1.58	3.76	3.78
Variance	0.180	0.207	1.034	1.055
Observations	15	15	15	15
Pooled Variance	0.194		1.044	
Hypothesized Mean Difference	0		0	
df	28		28	
t Stat	-0.144		-0.042	
P(T<=t) one-tail	0.443		0.483	
t Critical one-tail	1.701		1.701	
P(T<=t) two-tail	0.886		0.967	
t Critical two-tail	2.048		2.048	

Appendix C

All Data

Sample Date	Daily Avg Flow Rate cu.m/s	BL Daily Avg Flow Rate cu.m/s	HB Cl mM	BL Cl mM	HB SO4 mM
121104	12.7	12.7	0.920	1.05	0.628
121804	4.5	4.5	1.15	1.54	0.717
011205	56.4	56.4	0.298	0.457	0.214
012405	118.6	118.6	0.291	0.437	0.204
021405	24.9	24.9	0.942	1.08	0.630
022705	6.9	6.9	1.316	2.08	0.710
032105	15.2	15.2	2.26	2.56	0.895
061605	1.84	1.8	1.24	1.50	0.885
072005	3.3	3.3	1.13	1.26	0.671
082205	1.5	1.5	1.35	1.52	0.803
101105	9.1	9.1	1.32	1.83	0.749
101905	0.9	0.9	1.25	1.59	0.790
112805	2.9	2.9	1.18	1.32	0.612
122705	62.9	62.9	1.43	1.56	0.608
012406	17.8	17.8	0.894	1.23	0.449

Sample Date	BL SO4 mM	HB N-NO3 mM	BL N-NO3 mM	HB Na mM	BL Na mM
121104	0.667	0.259	0.229	0.619	0.787
121804	0.807	0.240	0.217	0.865	1.26
011205	0.247	0.068	0.109	0.259	0.403
012405	0.214	0.109	0.111	0.284	0.362
021405	0.669	0.266	0.233	0.822	1.17
022705	0.787	0.202	0.186	1.05	1.76
032105	0.797	0.140	0.145	1.79	2.08
061605	0.770	0.135	0.105	1.10	1.27
072005	0.619	0.110	0.076	1.10	1.21
082205	0.704	0.077	0.018	1.32	1.41
101105	0.894	0.113	0.155	1.12	1.52
101905	0.669	0.124	0.122	1.08	1.28
112805	0.552	0.309	0.339	0.862	0.719
122705	0.621	0.308	0.314	1.04	1.21
012406	0.487	0.230	0.214	0.754	1.10

Sample Date	HB K mM	BL K mM	HB Mg mM	BL Mg mM	HB Ca mM
121104	0.094	0.097	0.814	0.834	1.72
121804	0.089	0.105	0.977	1.00	2.10
011205	0.077	0.082	0.263	0.289	0.701
012405	0.086	0.088	0.280	0.300	0.703
021405	0.076	0.084	0.493	0.483	1.19
022705	0.068	0.081	0.832	0.910	1.89
032105	0.068	0.066	1.01	0.943	2.02
061605	0.096	0.091	1.00	0.947	1.78
072005	0.101	0.096	0.905	0.859	1.44
082205	0.126	0.110	0.907	0.804	1.45
101105	0.128	0.137	0.881	0.948	1.72
101905	0.128	0.126	0.895	0.826	1.69
112805	0.149	0.143	0.782	0.854	1.73
122705	0.117	0.118	0.903	0.880	1.88
012406	0.102	0.103	0.665	0.689	1.39

Sample Date	BL Ca mM	HB Sigma Cats	HB Sigma Anions	HB Calc Alk(HCO3-)	BL Ca mM
121104	1.79	5.78	1.81	3.98	1.79
121804	2.24	7.11	2.10	5.00	2.24
011205	0.747	2.26	0.58	1.69	0.747
012405	0.738	2.34	0.60	1.73	0.738
021405	1.22	4.27	1.84	2.43	1.22
022705	2.12	6.57	2.23	4.34	2.12
032105	1.90	7.91	3.29	4.62	1.90
061605	1.70	6.76	2.26	4.50	1.70
072005	1.42	5.89	1.91	3.99	1.42
082205	1.17	6.15	2.23	3.93	1.17
101105	1.92	6.44	2.18	4.27	1.92
101905	1.57	6.36	2.17	4.20	1.57
112805	1.90	6.04	2.10	3.95	1.90
122705	1.84	6.73	2.34	4.39	1.84
012406	1.48	4.97	1.57	3.40	1.48

Sample Date	HB Sigma Cats	HB Sigma Anions	HB Calc Alk(HCO3-)	BL Sigma Cats	BL Sigma Anions
121104	5.782	1.807	3.975	6.122	1.948
121804	7.105	2.104	5.001	7.844	2.564
011205	2.264	0.579	1.685	2.557	0.813
012405	2.338	0.604	1.734	2.527	0.762
021405	4.268	1.839	2.429	4.657	1.980
022705	6.566	2.229	4.337	7.897	3.055
032105	7.908	3.291	4.618	7.828	3.501
061605	6.761	2.259	4.502	6.654	2.370
072005	5.891	1.906	3.985	5.867	1.959
082205	6.154	2.228	3.926	5.478	2.240
101105	6.444	2.179	4.265	7.387	2.877
101905	6.364	2.166	4.198	6.194	2.376
112805	6.044	2.097	3.947	6.372	2.210
122705	6.729	2.344	4.385	6.770	2.497
012406	4.969	1.573	3.396	5.544	1.929

Sample Date	BL Calc Alk(HCO3-)	HB Ca+Mg mM	Bl Ca+Mg mM
121104	4.17	2.53	2.62
121804	5.28	3.06	3.24
011205	1.75	0.964	1.04
012405	1.77	0.984	1.04
021405	2.68	1.69	1.70
022705	4.84	2.73	3.03
032105	4.33	3.03	2.84
061605	4.28	2.79	2.65
072005	3.91	2.35	2.28
082205	3.24	2.36	1.98
101105	4.51	2.60	2.87
101905	3.82	2.58	2.40
112805	4.16	2.52	2.76
122705	4.27	2.79	2.72
012406	3.62	2.06	2.17